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National Eutrophication Survey, Corvallis, Oreg

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16. ABSTRACT

Annual total phosphorus and total nitrogen loadings to the lake were estimated and subdivided according to either point or non-point source origin. An assessment of the lake's trophic condition and limiting nutrient is also provided. All data collected by the U.S.E.P.A. National Eutrophication Survey during the one year study of the lake and its tributaries are included in the report.

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REPORT

ON

WRIGHT PATMAN (TEXARKANA) RESERVOIR

BOWIE AND CASS COUNTIES

TEXAS

EPA REGION VI

WORKING PAPER NO. 669

WITH THE COOPERATION OF THE

TEXAS WATER QUALITY BOARD

AND THE

TEXAS NATIONAL GUARD

MARCH, 1977

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FOREWORD

The National Eutrophication Survey was initiated in 1972 in response to an Administration commitment to investigate the nationwide threat of accelerated eutrophication to freshwater lakes and reservoirs.

OBJECTIVES

The Survey was designed to develop, in conjunction with state environmental agencies, information on nutrient sources, concentrations, and impact on selected freshwater lakes as a basis for formulating comprehensive and coordinated national, regional, and state management practices relating to point-source discharge reduction and non-point source pollution abatement in lake watersheds.

ANALYTIC APPROACH

The mathematical and statistical procedures selected for the Survey's eutrophication analysis are based on related concepts that:

a. A generalized representation or model relating sources, concentrations, and impacts can be constructed.

b. By applying measurements of relevant parameters associated with lake degradation, the generalized model can be transformed into an operational representation of a lake, its drainage basin, and related nutrients.

c. With such a transformation, an assessment of the potential for eutrophication control can be made.

LAKE ANALYSIS

In this report, the first stage of evaluation of lake and watershed data collected from the study lake and its drainage basin is documented. The report is formatted to provide state environmental agencies with specific information for basin planning [§303(e)], water quality criteria/standards review [§303(c)], clean lakes [§314(a,b)], and water quality monitoring [§106 and §305(b)] activities mandated by the Federal Water Pollution Control Act Amendments of 1972.

Beyond the single lake analysis, broader based correlations between nutrient concentrations (and loading) and trophic condition are being made to advance the rationale and data base for refinement of nutrient water quality criteria for the Nation's fresh water lakes. Likewise, multivariate evaluations for the relationships between land use, nutrient export, and trophic condition, by lake class or use, are being developed to assist in the formulation of planning guidelines and policies by EPA and to augment plans implementation by the states.

ACKNOWLEDGMENT

The staff of the National Eutrophication Survey (Office of Research & Development, U. S. Environmental Protection Agency) expresses sincere appreciation to the Texas Water Quality Board for professional involvement, to the Texas National Guard for conducting the tributary sampling phase of the Survey, and to those Texas wastewater treatment plant operators who voluntarily provided effluent samples.

Hugh C. Yantis, Jr., Executive Director of the Texas Water Quality Board, and John B. Latchford, Jr., Director, and the staff of the Field Operations Division provided invaluable lake documentation and counsel during the Survey, reviewed the preliminary reports, and provided critiques most useful in the preparation of this Working Paper series.

Major General Thomas Bishop, the Adjutant General of Texas, and Project Officer Colonel William L. Seals, who directed the volunteer efforts of the Texas National Guardsmen, are also gratefully acknowledged for their assistance to the Survey.

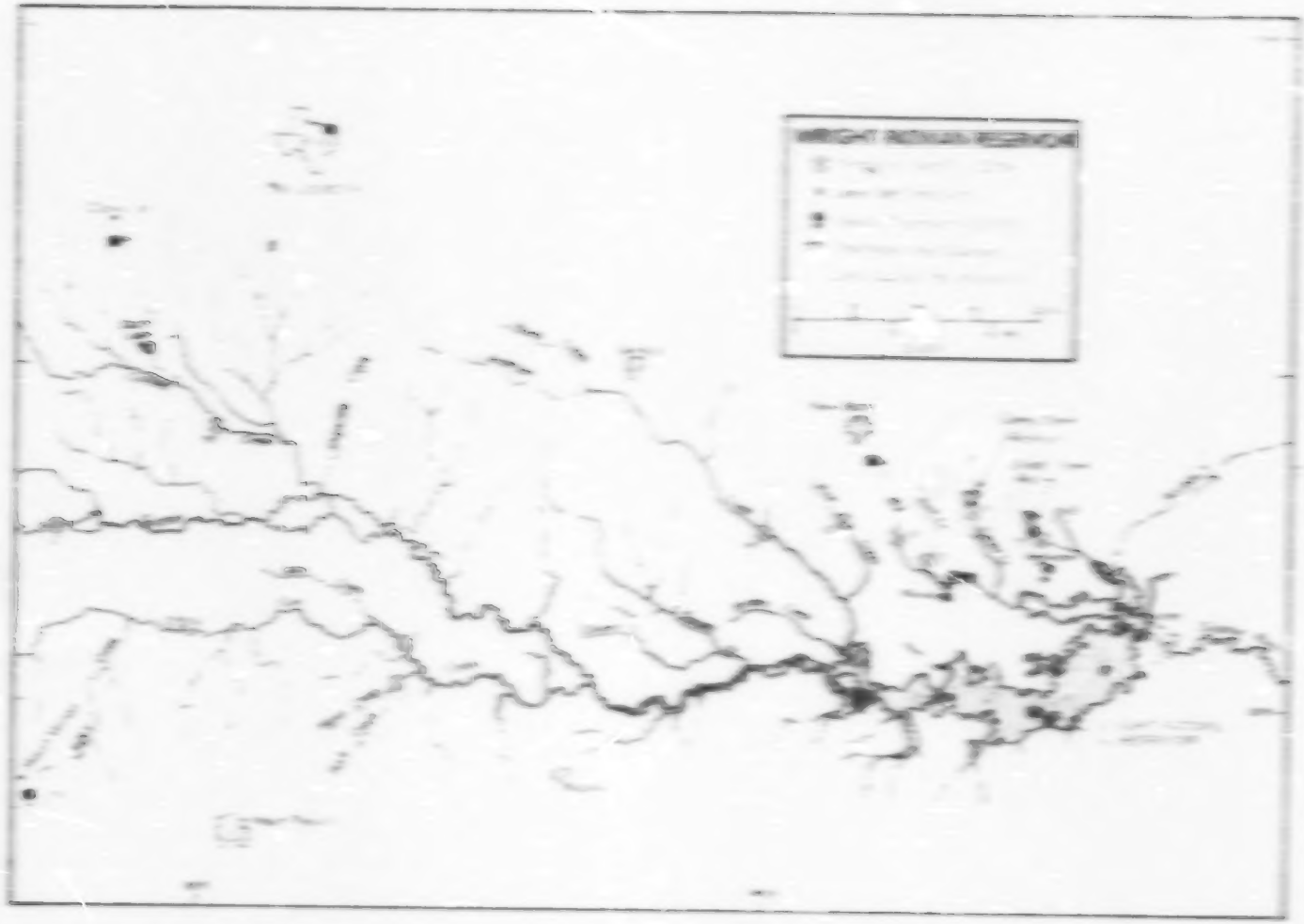
NATIONAL EUTROPHICATION SURVEY

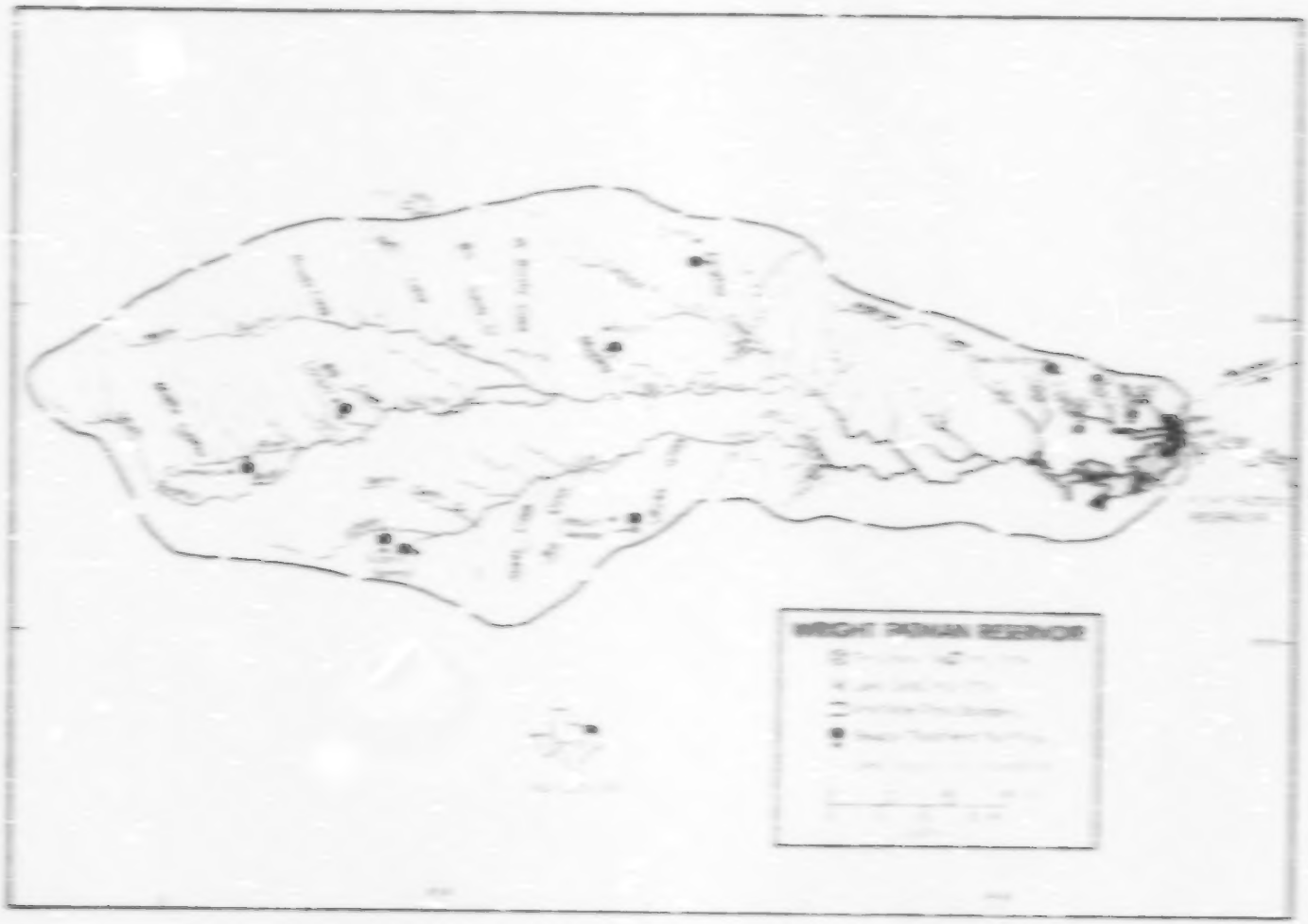
STUDY RESERVOIRS

State of Texas

NAME	COUNTY
Amistad	Val Verde
Bastrop	Bastrop
Belton	Bell, Coryell
Braunig	Bexar
Brownwood	Brown
Buchanan	Burnet, Llano
Caddo	Harrison, Marion, TX; Caddo Parish, LA
Calaveras	Bexar
Canyon	Comal
Colorado City	Mitchell
Corpus Christi	Jim Wells, Live Oak, San Patricio
Diversion	Archer, Baylor
Eagle Mountain	Tarrant, Wise
Fort Phantom Hill	Jones
Houston	Harris
Kemp	Baylor
Lake O'The Pines	Camp, Marion, Morris, Upshur
Lavon	Collin
Lewisville (Garza-Little Elm)	Denton
Livingston	Polk, San Jacinto, Trinity, Walker

Lyndon B. Johnson	Burnet, Llano
Medina	Bandera, Medina
Meredith	Hutchinson, Moore, Potter
O. C. Fisher (San Angelo)	Tom Green
Palestine	Anderson, Cherokee, Henderson, Smith
Possum Kingdom	Palo Pinto, Stephens, Young
Sam Rayburn	Angelina, Jasper Nacogdoches, Sabine, San Augustine
Somerville	Burleson, Lee, Washington
T. V. Spence	Coke
Stamford	Haskell
Stillhouse Hollow	Bell
Tawakoni	Hunt, Rains, Van Zandt
Texoma	Cooke, Grayson TX; Bryan, Johnston, Love, Marshall, OK
Travis	Burnet, Travis
Trinidad	Henderson
Twin Buttes	Tom Green
White River	Crosby
Whitney	Bosque, Hill
Wright Patman (Texarkana)	Bowie, Cass




WRIGHT PENNSYLVANIA

WRIGHT PATMAN (TEXARKANA) RESERVOIR

STORET NO. 4833

I. CONCLUSIONS

A. Trophic Condition:

Survey data indicate that Wright Patman Reservoir is eutrophic; i.e., well supplied with nutrients and quite productive. Whether nutrient enrichment is beneficial or deleterious depends on the actual or potential effect on the uses of the reservoir. In this regard, no nuisance conditions are known to personnel of the Texas Water Quality Board and there is little or no impairment of the designated beneficial uses of this water body.

Wright Patman Reservoir ranked thirty-third in overall trophic quality when the 39 Texas reservoirs sampled in 1974 were compared using a combination of six water quality parameters*. Thirty-four reservoirs had less median total phosphorus, 33 had less median dissolved orthophosphorus, 18 had less and one had the same median inorganic nitrogen, 32 had less mean chlorophyll A, and 33 had greater mean Secchi disc transparency.

Survey limnologists noted heavy growths of submerged and emergent vegetation at station 4 during the March, May, and November sampling visits.

* See Appendix A.

B. Rate-Limiting Nutrient:

The algal assay results indicate that Wright Patman Reservoir was limited by nitrogen at the time the samples were taken (03/22/74 and 11/08/74). The reservoir data indicate nitrogen limitation at all sampling times and stations.

C. Nutrient Controllability:

1. Point sources--During the sampling year, point sources contributed an estimated 13.8% of the total phosphorus load to Wright Patman Reservoir. The wastewater treatment plants at Sulphur Springs contributed 4.5%, the plant at Commerce contributed 3.9%, and seven other municipal facilities collectively contributed 5.4%. In addition, nine other domestic wastewater treatment plants discharge to tributaries in the drainage basin (Wyatt, 1976) beyond the 40-kilometer limit of the Survey*. These sources may be significant as indicated by the phosphorus export rates of Sulphur River and Cuthand Creek (see discussion below).

The present phosphorus loading of 2.05 g/m^2/year is more than two times that proposed by Vollenweider (Vollenweider and Dillon, 1974) as a eutrophic loading (see page 18). However, even complete removal of phosphorus at the listed point sources would only reduce the loading to 1.77 g/m^2/year; and, regardless of the applicability of Vollenweider's eutrophic level to Texas reservoirs, because of the persistent nitrogen-limited condition of the reservoir, it does

* See Working Paper No. 175, "...Survey Methods 1973-1976".

not see likely that control of phosphorus at these sources would result in a shift to phosphorus limitation. Further investigation is needed to more accurately determine the controllability of phosphorus from all sources in the drainage basin, including land-use practices (see non-point discussion below).

There was an apparent phosphorus loss from the reservoir during the sampling year (see page 16). This probably is due in part to the great distances that the sampling sites were located upstream from the reservoir (see map, page vii); i.e., the entire phosphorus load from each drainage area would not have been measured. Also, it is possible that the loss may be the result of underestimation of point sources which discharge below tributary sampling sites; e.g., to Sulphur River below L-1 and Cuthand Creek below M-1.

2. Non-point sources--Non-point sources contributed an estimated 86.2% of the total phosphorus input to Wright Patman Reservoir during the sampling year. The Sulphur River contributed 44.4%, and seven other gaged tributaries collectively contributed 21.0% of the total. Ungaged minor tributaries and immediate drainage were estimated to have contributed 19.9%.

The phosphorus export rates of Sulphur River (32 g/km^2/year) and Cuthand Creek (29 kg/km^2/year) were appreciably higher than the rates of the other measured tributaries in the drainage basin (see page 17). This may be indicative of an underestimation of point sources impacting these streams, the impact of point sources

beyond the 40-kilometer survey limit, or land-use practices. However, the export rates of the tributaries of this reservoir are similar to the rates of the tributaries of nearby Lake of the Pines* and may be typical of this part of the state because of greater precipitation.

* Working Paper No. 648

II. RESERVOIR AND DRAINAGE BASIN CHARACTERISTICS†

A. Morphometry††:

1. Surface area: 126.13 kilometers².

2. Mean depth: 3.0 meters.

3. Maximum depth: 24.0 meters.

4. Volume: 373,727 x 10⁶ m³.

5. Mean hydraulic retention time: 57 days.

B. Tributary and Outlet:
(See Appendix C for flow data)

1. Tributaries -

Name	Drainage area (km²)*	Mean flow (m³/sec)*
Rock Creek	27.2	0.203
Elliot Creek	21.5	0.160
Caney Creek	18.4	0.135
Big Creek	40.4	0.297
Rice Creek	46.6	0.342
White Oak Creek	1,712.0	13.340
Sulphur River	3,535.3	29.960
Cuthand Creek	600.9	5.160
Minor tributaries & immediate drainage -	2,789.0	25.920
Totals	8,791.3	75.517

2. Outlet -

Aqueduct	0.0	1.28/**
Sulphur River	8,917.4	74.620
Totals	8,917.4***	75.907

† Table of metric conversions--Appendix B.
†† Laurent, 1976 (mean volume and surface area in 1974).
* For limits of accuracy, see Working Paper No. 175.
** Anonymous, 1975.
*** Includes area of reservoir.

C. Precipitation*

1. Year of sampling: 156.5 centimeters.

2. Mean annual: 118.4 centimeters.

* See Working Paper No. 179.

III. WATER QUALITY SUMMARY

Wright Patman Reservoir was sampled four times during 1974 by means of a pontoon-equipped Huey helicopter. Each time, samples for physical and chemical parameters were collected from one or more depths at four stations on the reservoir (see map, page vi). During each visit, a single depth-integrated (4.6 m or near bottom to surface) sample was composited from the stations for phytoplankton identification and enumeration; and during the first visit, a single 18.9-liter depth-integrated sample was composited for algal assays. Also each time, a depth-integrated sample was collected from each of the stations for chlorophyll a analysis. The maximum depths sampled were 4.6 meters at stations 1 and 2, 4.9 meters at station 3, and 1.5 meters at station 4.

The sampling results are presented in full in Appendix D and are summarized in the following table (August nutrient samples were not preserved properly and were not analyzed).

[illegible]

[illegible]	1ST SAMPLING (3/22/94)			2ND SAMPLING (6/22/94)			3RD SAMPLING (9/21/94)		
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	13.0 - 38.0	25.1	25.0	27.0 - 28.0	27.0	27.0	28.2 - 38.1	28.2	25.2
[illegible]	7.7 - 8.4	8.7	8.0	7.9 - 7.2	8.7	8.0	7.0 - 7.6	7.1	7.0
[illegible]	171. - 271.	213.	197.	23.. - 25..	25.	24.	19.. - 24..	22.	21.
[illegible]	7.7 - 7.9	7.1	7.0	7.0 - 7.2	7.0	7.0	7.0 - 8.2	7.0	7.0
[illegible]	7. - 75.	48.	41.	7. - 15.	10.	9.	[illegible]	[illegible]	[illegible]
[illegible]	0.049 - 0.198	0.097	0.092	0.073 - 0.197	0.11	0.07	[illegible]	[illegible]	[illegible]
[illegible]	0.031 - 0.047	0.037	0.026	0.01 - 0.06	0.025	0.022	[illegible]	[illegible]	[illegible]
[illegible]	0.07 - 0.14	0.09	0.0	0.08 - 0.17	0.09	0.07	[illegible]	[illegible]	[illegible]
[illegible]	0.03 - 0.13	0.05	0.05	0.04 - 0.12	0.07	0.05	[illegible]	[illegible]	[illegible]
[illegible]	0.48 - 1.88	0.75	0.75	0.46 - 1.88	0.77	1.08	[illegible]	[illegible]	[illegible]
[illegible]	0.04 - 0.18	0.11	0.0	0.12 - 0.27	0.17	0.1	[illegible]	[illegible]	[illegible]
[illegible]	0.13 - 1.15	0.47	0.4	0.08 - 1.06	0.47	0.4	[illegible]	[illegible]	[illegible]
[illegible]	17.. - 24..	21.	14.	3.. - 12.	15.	10.	13.7 - 15..	15.	15.
[illegible]	8.7 - 8.7	8.0	8.0	8.0 - 8.0	8.0	8.0	8.0 - 8.0	8.7	7.7

[illegible]

[illegible]

[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
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[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]

B. Biological characteristics:

1. Phytoplankton -

Sampling Date	Dominant Genera	Algal Units per ml
03/22/74	1. Melosira sp.	5,495
	2. Centric diatoms	1,672
	3. Nitzschia sp.	1,593
	4. Chroomonas sp.	1,274
	5. Dactylococcopsis sp.	637
	Other genera	1,552
	Total	12,223
05/31/74	1. Centric diatoms	4,824
	2. Melosira sp.	1,495
	3. Pennate diatoms	1,158
	4. Chroomonas sp.	679
	5. Merismopedia sp.	338
	Other genera	1,846
	Total	10,240
08/23/74	1. Melosira sp.	2,795
	2. Oscillatoria sp.	2,056
	3. Nitzschia sp.	1,529
	4. Lyngbya sp.	1,002
	5. Dactylococcopsis sp.	738
	Other genera	3,586
	Total	11,706
11/08/74	1. Melosira sp.	1,211
	2. Chroomonas sp.	413
	3. Dactylococcopsis sp.	330
	4. Oscillatoria sp.	248
	5. Nitzschia sp.	221
	Other genera	1,294
	Total	3,717

2. Chlorophyll a -

Sampling Date	Station Number	Chlorophyll a (µg/l)
03/22/74	1	10.0
	2	11.9
	3	24.0
	4	16.1
05/31/74	1	14.1
	2	32.1
	3	57.0
	4	53.0
08/23/74	1	13.7
	2	15.2
	3	10.8
	4	15.5
11/08/74	1	2.6
	2	13.2
	3	3.7
	4	1.5

C. Limiting Nutrient Study:

1. Autoclaved, filtered, and nutrient spiked -

a. March sample

Spike (mg/l)	Ortho P Conc. (mg/l)	Inorganic N Conc. (mg/l)	Maximum yield (mg/l-dry wt.)
Control	0.040	0.143	5.5
0.050 P	0.090	0.143	5.4
0.050 P + 1.0 N	0.090	1.143	21.9
1.0 N	0.040	1.143	15.6

b. November sample

Spike (mg/l)	Ortho P Conc. (mg/l)	Inorganic N Conc. (mg/l)	Maximum yield (mg/l-dry wt.)
Control	0.086	0.043	1.3
0.050 P	0.136	0.043	1.3
0.050 P + 1.0 N	0.136	1.043	27.5
1.0 N	0.086	1.043	28.2

2. Discussion -

The control yields of the assay alga, Selenastrum capricornutum, indicate that the potential primary productivity of Wright Patman Reservoir was moderately high at the times the samples were collected (03/22/74 and 11/6/74). Also, in both assays, the lack of increase in yield with the addition of phosphorus until nitrogen was also added, indicates that the reservoir was limited by nitrogen at those times. Note that the addition of nitrogen alone resulted in yields much greater than those of the controls.

The reservoir data indicate nitrogen limitation as well; i.e., the mean inorganic nitrogen to orthophosphorus ratios were 9 to 1 or less at all sampling stations and times, and nitrogen limitation would be expected.

IV. NUTRIENT LOADINGS
(See Appendix E for data)

For the determination of nutrient loadings, the Texas National Guard collected monthly near-surface grab samples from each of the tributary sites indicated on the map (page vii), except for the months of April and May when two samples were collected. Sampling was begun in September, 1974, and was completed in August, 1975.

Through an interagency agreement, stream flow estimates for the year of sampling and a "normalized" or average year were provided by the Texas District Office of the U.S. Geological Survey for the tributary sites nearest the reservoir.

In this report, nutrient loads for sampled tributaries were calculated using mean annual concentrations and mean annual flows. Nutrient loads shown are those measured minus point-source loads, if any. Nutrient loads for the aqueduct were calculated using the mean concentrations measured in the Sulphur River outlet (station A-1) and multiplying by the mean aqueduct flow.

Nutrient loads for unsampled "minor tributaries and immediate drainage" ("ZZ" of U.S.G.S.) were estimated using the mean concentrations in Rock Creek at station C-1 and the mean ZZ flow.

The operators of the Maud and Redwater wastewater treatment plants provided monthly effluent samples and corresponding flow data. The nine other listed wastewater treatment plants did not participate; nutrient loads from these sources were estimated at 1.134 kg P and 3.401 kg N/capita/year, and flows were estimated at 0.3785 m^3/capita/day.

A. Waste Sources:

1. Known municipal* -

Name	Pop. Served	Treatment	Mean Flow (m^3/d)	Receiving Water
Maud**	1,100	act. sludge	241.9	Wright Patman Reservoir
Redwater**	450	stab. pond	49.2	Wright Patman Reservoir
New Boston	6,000	ox. ditch	1,059.8	Big Creek
Clarksville	3,600	tr. filter	1,362.6	Langford Creek
Bogata	800	stab. pond	302.8	L. Mustang Creek
Mount Vernon	1,200	stab. pond	454.2	Trib. of White Oak Creek
Commerce	6,800	stab. pond	3,330.8	Middle Sulphur River
Sulphur Springs				
old plant	8,000	tr. filter	3,028.0	White Oak Creek
SE plant	2,300	stab. pond	870.6	Rock Creek
Cooper	3,400	act. sludge	1,286.9	Trib. of Sulphur River

There are nine additional municipal facilities which discharge to tributaries within the drainage basin beyond the 40-kilometer limit of the Survey†. These include De Kalb South, Red River Army Depot, Annona, Talco, Blossom, Roxton (Lamar County WCID No. 1), Pecan Gap, Ladonia, and Wolfe City (Wyatt, 1976).

2. Industrial - Unknown

* Anonymous, 1971.
** Treatment plant questionnaires.
† See Working Paper No. 175.

B. Annual Total Phosphorus Loading - Average Year:

1. Inputs -

Source	kg P/ yr	% of total
a. Tributaries (non-point load) -		
Rock Creek	405	0.2
Elliot Creek	210	<0.1
Caney Creek	225	0.1
Big Creek	245	0.1
Rice Creek	960	0.4
White Oak Creek	34,920	13.5
Sulphur River	114,660	44.4
Cuthand Creek	17,410	6.7
b. Minor tributaries & immediate drainage (non-point load) -	51,495	19.9
c. Known municipal STP's -		
Maud	565	0.2
Redwater	170	<0.1
New Boston	3,175	1.2
Clarksville	4,080	1.6
Bogata	905	0.4
Mount Vernon	1,360	0.5
Commerce	9,980	3.9
Sulphur Springs old plant	9,070	3.5
SE plant	2,610	1.0
Cooper	3,955	1.5
d. Septic tanks - Unknown	?	-
e. Industrial - Unknown	?	-
f. Direct precipitation* -	2,295	0.9
Total	258,495	100.0

* See Working Paper No. 175.

2. Outputs -

	kg P/yr
Lake outlet - Aqueduct	4,990
Sulphur River	289,445
Total	294,435

3. Net annual P loss - 35,940 kg.

C. Annual Total Nitrogen Loading - Average Year:

1. Inputs -

Source	kg N/yr	% of total
a. Tributaries (non-point load) -		
Rock Creek	4,330	0.2
Elliot Creek	3,350	0.2
Caney Creek	3,035	0.1
Rig Creek	1,020	<0.1
Rice Creek	9,145	0.4
White Oak Creek	388,310	16.4
Sulphur River	946,790	40.9
Cuthand Creek	167,770	7.2
b. Miror tributaries & immediate drainage (non-point load) -	552,570	23.8
c. Known municipal STP's -		
Maud	635	<0.1
Redwater	270	<0.1
New Boston	9,525	0.4
Clarksville	12,245	0.5
Bogata	2,720	0.1
Mount Vernon	4,080	0.2
Commerce	29,930	1.3
Sulphur Springs old plant	27,210	1.2
SE plant	7,820	0.3
Cooper	11,560	0.5

Source	kg N/yr	% of total
d. Septic tanks - Unknown	?	-
e. Industrial - Unknown	?	-
f. Direct precipitation* -	136,170	5.9
Total	2,318,485	100.0

2. Outputs -

Lake outlet - Aqueduct	38,110	
Sulphur River	2,209,670	
total	2,247,780	

3. Net annual N accumulation - 70,705 kg.

D. Non-point Nutrient Export by Subdrainage Area:

Tributary	kg P/km²/yr	kg N/km²/yr
Rock Creek	15	159
Elliot Creek	10	156
Caney Creek	12	169
Big Creek	6	25
Rice Creek	20	196
White Oak Creek	20	227
Sulphur River	32	268
Cuthand Creek	29	279

E. Mean Nutrient Concentrations in Ungaged Streams:

Tributary	Mean Total P Conc. (mg/l)	Mean Total N Conc. (mg/l)
E. Fork Elliot Creek	0.172	2.247
Anderson Creek	0.160	1.225
Horse Creek	0.109	0.920

* See Working Paper No. 175.

F. Yearly Loads:

In the following table, the existing phosphorus loadings are compared to those proposed by Vollenweider (Vollenweider and Dillon, 1974). Essentially, his "dangerous" loading is one at which the receiving water would become eutrophic or remain eutrophic; his "permissible" loading is that which would result in the receiving water remaining oligotrophic or becoming oligotrophic if morphometry permitted. A mesotrophic loading would be considered one between "dangerous" and "permissible".

Note that Vollenweider's model may not be applicable to water bodies with short hydraulic retention times.

	Total Phosphorus		Total Nitrogen	
	Total	Accumulated	Total	Accumulated
grams/m^2/yr	2.05	loss[a]	18.4	0.6

Vollenweider phosphorus loadings ($g/m^2/yr$) based on mean depth and mean hydraulic retention time of Wright Patman Reservoir:

"Dangerous" (eutrophic loading)	0.84
"Permissible" (oligotrophic loading)	0.42

[a] There was an apparent loss of phosphorus during the sampling year. This would not be expected to occur even in a reservoir with a mean hydraulic retention time of only 57 days. This may indicate unknown point sources which discharge directly to the reservoir, underestimation of phosphorus loads from the point sources discharging directly to the reservoir, resolubilization of previously sedimented phosphorus, or tributary sampling sites located too far upstream (see map, page vii).

V. LITERATURE REVIEWED

Anonymous, 1971. Inventory of municipal waste facilities, EPA Publ. OWP-1, vol. 6, Wash., DC.

Anonymous, 1975. Water resources data for Texas. Part 1: Surface water records. U.S. Geol. Surv., Austin.

Laurent, Arthur, 1976. Personal communication (lake morphometry). Army Corps of Engineers, New Orleans Dist., New Orleans.

Vollenweider, R. A., and P. J. Dillon, 1974. The application of the phosphorus loading concept to eutrophication research. Natl. Res. Council of Canada Publ. No. 13690, Canada Centre for Inland Waters, Burlington, Ontario.

VI. APPENDICES

APPENDIX A

LAKE RANKINGS

LAKE CODE	LAKE NAME	[illegible] TOTAL *	[illegible] [illegible] *	[illegible] [illegible]	[illegible] [illegible]	[illegible] [illegible]	[illegible] [illegible] *
[illegible]	[illegible] LAKE	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible] LAKE	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible] [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

[illegible]

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

PERCENT OF LAKES WITH HIGHER VALUES (NUMBER OF LAKES WITH HIGHER VALUES)

LAKE CODE	LAKE NAME	[illegible] TOTAL P	[illegible] INORG N	[illegible] ALK	[illegible] CHLA	[illegible] SD	[illegible] DISS ORTHO P	[illegible] NO
[illegible]	[illegible] LAKE	29 (11)	55 (21)	24 (9)	3 (1)	67 (25)	38 (10)	254
[illegible]	[illegible] LAKE	19 (7)	47 (17)	5 (2)	19 (7)	62 (23)	39 (14)	254
[illegible]	[illegible] LAKE [illegible]	69 (33)	37 (14)	67 (33)	42 (25)	17 (6)	51 (14)	372
[illegible]	[illegible] LAKE	32 (12)	78 (29)	37 (14)	21 (8)	63 (24)	38 (10)	253
[illegible]	[illegible] LAKE	11 (4)	51 (14)	13 (5)	16 (6)	72 (27)	13 (5)	176
[illegible]	[illegible] LAKE	39 (14)	34 (13)	61 (23)	45 (17)	17 (6)	21 (7)	217
[illegible]	[illegible] LAKE	88 (33)	21 (7)	92 (35)	82 (31)	17 (6)	94 (33)	264
[illegible]	[illegible]	8 (3)	61 (22)	11 (4)	5 (2)	92 (35)	8 (3)	269
[illegible]	[illegible] [illegible] [illegible]	59 (22)	21 (7)	55 (22)	91 (33)	49 (17)	63 (23)	311
[illegible]	[illegible] [illegible] [illegible]	84 (32)	61 (22)	76 (29)	89 (34)	17 (6)	62 (23)	340
[illegible]	[illegible] LAKE	62 (24)	51 (19)	79 (30)	71 (27)	17 (6)	76 (29)	357

LAKES RANKED BY INDEX NO.

RANK	LAKE CODE	LAKE NAME	INDEX NO.
29	[illegible]	LYNDON B JOHNSON LAKE	239
30	[illegible]	TEXANA LAKE	217
31	[illegible]	SOMERVILLE LAKE	200
32	[illegible]	SAN ANGELO RESERVOIR	200
33	[illegible]	TEMPLINE LAKE	176
34	[illegible]	SANTA ROSA LAKE	173
35	[illegible]	TRINIDAD	164
36	[illegible]	BRYANS LAKE	159
37	[illegible]	CORPUS CHRISTI LAKE	155
38	[illegible]	HOUSTON LAKE	139
39	[illegible]	LIVINGSTON LAKE	91

APPENDIX B

CONVERSION FACTORS

CONVERSION FACTORS

Hectares x 2.471 = acres

Kilometers x 0.6214 = miles

Meters x 3.281 = feet

Cubic meters x 8.107×10^{-4} = acre/feet

Square kilometers x 0.3861 = square miles

Cubic meters/sec x 35.315 = cubic feet/sec

Centimeters x 0.3937 = inches

Kilograms x 2.205 = pounds

Kilograms/square kilometer x 5.711 = lbs/square mile

APPENDIX C

TRIBUTARY FLOW DATA

[illegible]

[illegible]

TOTAL [illegible] AREA OF [illegible] =

[illegible]	DRAINAGE AREA(SQ KM)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

SUMMARY

TOTAL DRAINAGE AREA OF LAKE = [illegible]
SUM OF SUB-DRAINAGE AREAS = [illegible]

TOTAL FLOW IN = [illegible]
TOTAL FLOW OUT = [illegible]

NOTE [illegible]

MEAN MONTHLY FLOWS AND DAILY FLOWS(CMS)

[illegible]	MONTH	YEAR	MEAN FLOW	DAY	FLOW	DAY	FLOW	DAY	FLOW
[illegible]	9	74	119.397	7	49.149				
	10	74	117.232	6	178.467				
	11	74	278.936	18	299.632				
	12	74	283.461	9	286.800				
	1	75	144.982	11	252.485				
	2	75	241.824	4	299.432				
	3	75	293.169	6	293.146				
	4	75	134.561	5	299.839	24	119.451		
	5	75	169.195	3	9.243	17	241.482		
	6	75	127.842	7	184.419				
	7	75	10.742	12	14.451				
	8	75	11.267	9	14.781				
[illegible]	9	74	4.139	7	8.825				
	10	74	8.791	6	8.843				
	11	74	1.381	10	5.425				
	12	74	8.791	9	2.246				
	1	75	8.125	11	8.110				
	2	75	1.797	4	1.471				
	3	75	8.648	8	8.246				
	4	75	3.351	5	8.841	24	8.[illegible]		
	5	75	8.471	3	4.478	17	8.[illegible]		
	6	75	8.[illegible]	7	8.[illegible]				
	7	75	8.[illegible]	12	8.[illegible]				
	8	75	8.848	9	8.842				

APPENDIX D

PHYSICAL and CHEMICAL DATA

[illegible]

[illegible]

DATE	TIME	DEPTH	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
FROM	OF		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
TO	DAY	FEET	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	10	10	[illegible]	[illegible]		25	177	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	10	10	[illegible]	[illegible]	[illegible]		177					
	10	10	[illegible]	[illegible]	[illegible]		176	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	13	30	[illegible]	[illegible]		36	240	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	13	30	[illegible]	[illegible]	[illegible]		242	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	13	30	[illegible]	[illegible]	[illegible]		240	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	11	45	[illegible]	[illegible]	[illegible]	30	263	[illegible]				
	11	45	[illegible]	[illegible]	[illegible]		252	[illegible]				
[illegible]	09	05	[illegible]	[illegible]	[illegible]	23	110	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	09	05	[illegible]	[illegible]			109	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	09	05	[illegible]	[illegible]	[illegible]		110	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

DATE	TIME	DEPTH	[illegible]	[illegible]	[illegible]
FROM	OF		[illegible]	[illegible]	[illegible]
TO	DAY	FEET	[illegible]	[illegible]	[illegible]
[illegible]	10	10	[illegible]	11.9	
	10	10	[illegible]		
[illegible]	13	30	[illegible]	32.1	
	13	30	[illegible]		
	13	30	[illegible]		
[illegible]	11	45	[illegible]	25.2	
[illegible]	09	05	[illegible]	13.7	
	09	05	[illegible]		
	09	05	[illegible]		

APPENDIX E

TRIBUTARY AND WASTEWATER TREATMENT PLANT DATA

[illegible] METEOROLOGICAL DATA FOR [illegible]

[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]

DATE	TIME	DEPTH	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	OF		[illegible]	%	[illegible]	[illegible]	
ID	DAY	FEET	MG/L	MG/L	MG/L	MG/L +	MG/L +
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

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[illegible]							

* VALUE PRIOR TO BE
LESS THAN INDICATED

[illegible]

[illegible]

[illegible]

DATE	TIME	DEPTH	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	OF		[illegible]	%	TOTAL	[illegible]	
TO	DAY	FEET	MG/L	MG/L	MG/L	MG/L -	MG/L -
[illegible]							
[illegible]							
[illegible]							
[illegible]							
[illegible]							
[illegible]							
[illegible]							
[illegible]							
[illegible]							
[illegible]							

[illegible] HISTORICAL DATA [illegible]

[illegible]

DATE	TIME	DEPTH	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
FROM	OF		[illegible]	%	TOTAL	[illegible]	
TO	DAY	FEET	MG/L	MG/L	MG/L	MG/L *	MG/L *
74/12/17	14	40	0.035	0.370	0.245	0.767	0.731
74/10/15	14	30	0.049	0.451	0.340	0.956	0.907
74/11/12	14	45	0.586	0.455	0.377	0.956	0.911
74/12/09	09	30	0.819	0.403	0.284	0.815	0.696
75/01/14	12	15	0.884	0.700	0.549	0.176	0.751
75/02/09	09	15	0.897	0.331	0.815	0.496	0.478
75/03/09	09	35	0.811	0.479	0.425	0.499	0.886
75/04/15	04	35	0.440	0.709	0.632	0.259	0.384
75/04/15	09	10	0.586	0.556	0.478	0.224	0.456
75/05/13	09	00	0.895	0.986	0.695	0.246	0.326
75/05/17	04	15	0.123	0.756	0.595	0.185	0.496
75/05/24	14	20	0.448	0.488	0.439	0.818	0.378
75/06/07	09	20	0.897	0.958	0.390	0.8859	0.828
75/06/05	10	00	0.364	0.485	0.816	0.856	0.225

* VALUE KNOWN TO BE
LESS THAN INDICATED

[illegible]

[illegible]

DATE	TIME	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
YR	DAY	FEET	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

* VALUE KNOWN TO BE
LESS THAN INDICATED

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* [illegible]
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DATE	TIME	DEPTH	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	OF		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
TU	DAY	FEET	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

[illegible]
[illegible]

[illegible]

[illegible]

DATE	TIME	DEPTH	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
FROM	TO	FEET	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]									
04/08/12	11	07							
[illegible]			0.046	3.48	0.358	14.488	15.48n	0.045	0.045
04/09/12	25	01							
04/14/26	22	07							
[illegible]			0.035	5.278	1.254	5.758	0.386	0.055	0.055
04/14/26	25	07							
04/16/23	18	15							
[illegible]			0.578	2.188	0.044	12.588		0.045	0.049
04/16/23	25	04							
04/16/25	11	05							
[illegible]			0.468	2.488	0.428	3.118	3.288	0.046	0.048
04/16/25	26	07							
04/12/14	18	48							
[illegible]			0.578	1.488	*0.038*	0.588	0.458	0.086	0.075
04/12/14	25	38							
05/01/27	24	18	0.046	3.488	0.258		5.488	0.045	0.078
05/02/24	12	38	0.380	5.488	2.748	2.128		0.078	0.078
05/03/28	24	28	0.048	5.588	1.458	2.388	0.488	0.045	0.075
05/04/17	20	08	0.488	0.588*	0.058*	0.388	0.488	0.048	0.085
05/05/27	28	05	0.388	0.758	0.248	5.028	5.288	0.045	0.088
05/06/27	28	38	0.788	2.788	0.328	7.868	7.488	0.048	0.088
05/07/25	26	08		0.388	0.128	0.758	0.488	0.088	0.085
05/08/04	04	48	0.488	2.488	0.058*	11.888	11.588	0.058	0.088

* VALUE KNOWN TO BE
LESS THAN INDICATED